



Points: 30

Time: 3 Hours

Science for Sustainable Food and Agriculture

Multiple Choice Test

December 3, 2023

You may turn to the next **TWO** pages to
read the “EXAMINATION RULES” and “EXAM INSTRUCTIONS”

EXAMINATION RULES

- | | |
|---|---|
| <ol style="list-style-type: none"> 1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment. 2. You must sit at your designated desk. 3. Do NOT start reading or answering the questions before the “START” signal. 4. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator. 5. If you need to visit the bathroom, please raise the "fan" provided on the table. |  <p>provided "fan"</p> |
|---|---|
6. Do **NOT** disturb other competitors. If you need any assistance, raise your "fan" and wait for a supervisor to come.
 7. Do **NOT** discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
 8. At the end of the examination time you will hear the “**STOP**” signal. You are **NOT** allowed to write anything after the signal is given. Arrange the exam, answer sheets, and the stationery items (pen, pencil, eraser, calculator, and fan) neatly on your desk. Do **NOT** leave the room before all the answer sheets have been collected by exam supervisors, and you are given the signal to leave.
 9. There will be only one warning if you do not comply with the examination rules. Any failure to comply with the rules or instructions of supervisors after the warning results in disqualification, receiving total of zero points in the multiple choice test.

You may turn to the exam instructions on the next page



EXAM INSTRUCTIONS

1. After the “**START**” signal, you will have 3 hours to complete the exam.
2. Check the stationery items (pen, pencil, eraser, calculator, and fan) provided by the organizers. **ONLY** use the pen and pencil provided by the organizers.
3. No additional scratch paper is provided. You may use the question sheets and their backside as scratch paper.
4. Check that your name, code and country are on your answer sheet and sign your answer sheet. Raise your “fan”, if you do not have the answer sheet.
5. Read each problem carefully and indicate your answer on the answer sheet by filling in the circle for the answer only with **PENCIL** (as shown below). There is only one correct answer for each question.

Example: (B) is your answer.

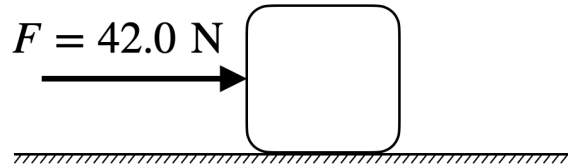


6. If you want to change your answer, completely erase your first answer and fill in your new answer. Any ambiguous answers are marked as wrong.
7. Only the answer sheet will be evaluated. Before filling in your answers on the answer sheet, use the question sheets as scratch paper.
8. Point rules
 - Correct answer : + 1 point
 - Wrong answer : - 0.25 points
 - No answer : 0 points
9. Check that you have a complete set of the exam question sheets after the “**START**” signal is given. Raise your “fan”, if you find any missing sheets. There are total of **30 questions in 36 pages total** including front cover and instruction pages. There is only **one page** of the answer sheet.
10. Useful information is provided on **the following page**.

DO NOT turn to the next page before the

"START SIGNAL"

1. A box with a weight of 100 N is at rest on a horizontal surface. The coefficient of kinetic friction and the coefficient of static friction between the box and the surface are $\mu_k = 0.400$ and $\mu_s = 0.500$, respectively. If the force $F = 42.0$ N is applied on the box as shown in the figure, what is the magnitude and direction of the friction acting on the box?

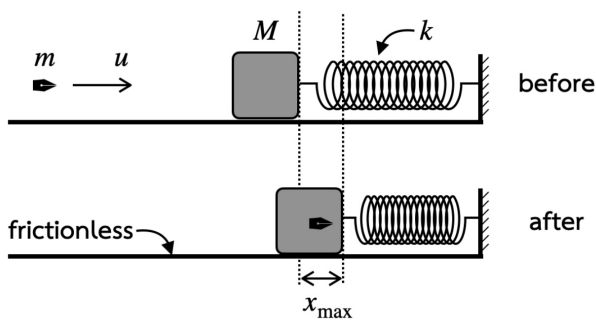


A.	40.0 N to the left
B.	42.0 N to the left
C.	50.0 N to the left
D.	50.0 N to the right

2. Which object has the greatest magnitude of the acceleration? Assume that all objects move with constant acceleration in straight line.

A.	A vehicle accelerates from rest to 100 km/h within 4.00 s.
B.	A rock during a free fall near the surface of the Earth.
C.	A vehicle with an initial speed of 60.0 km/h comes to rest in 3.20 s.
D.	A vehicle starting from rest takes 6.50 s to cover a distance of 250 m.

3. A bullet of mass m is shot into a stationary block of mass M . The block rests on a frictionless floor and is attached to a massless spring with a spring constant k . The bullet embeds itself in the block upon impact. Subsequently, the combined mass compresses the spring to a maximum displacement of $x_{\max}$, as illustrated in the figure. Determine the initial velocity u of the bullet in terms of m , M , k and $x_{\max}$.



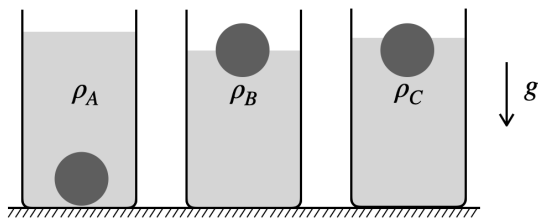
A.	$\frac{x_{\max}}{m} \sqrt{k(m+M)}$
B.	$\frac{(m+M)}{m} x_{\max} \sqrt{k}$
C.	$x_{\max} \sqrt{\frac{k}{m}}$
D.	$x_{\max} \sqrt{\frac{k}{m+M}}$

4. When placed in a liquid of density ρ_A , a sphere sinks and displaces a volume V_A of liquid, as shown in the figure.

When placed in a liquid of density ρ_B , the same sphere floats with half of its volume appears over the surface of the liquid.

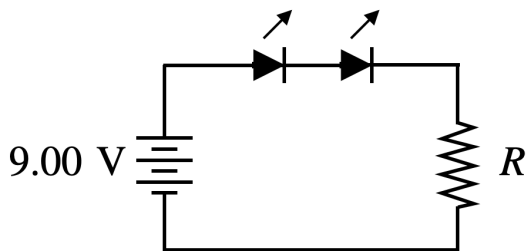
When placed in a liquid of density ρ_C , the same sphere floats.

Determine the magnitude of the buoyant force exerted by the liquid of density ρ_C on the sphere.



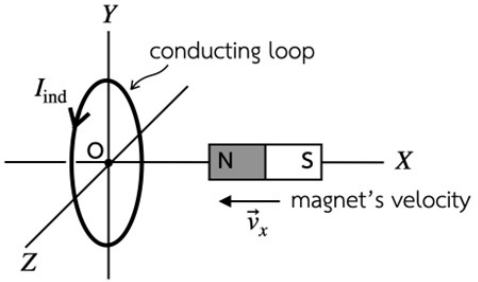
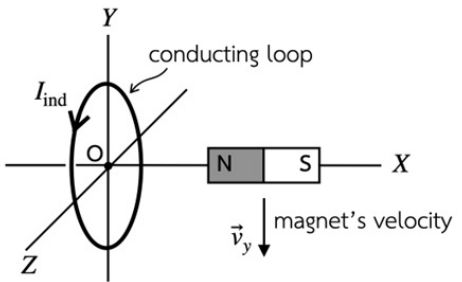
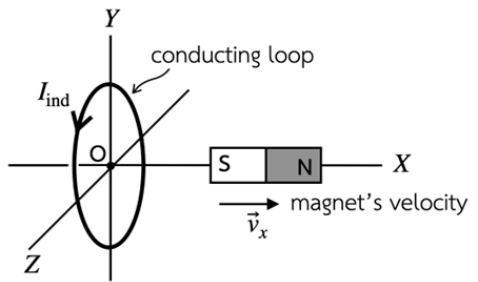
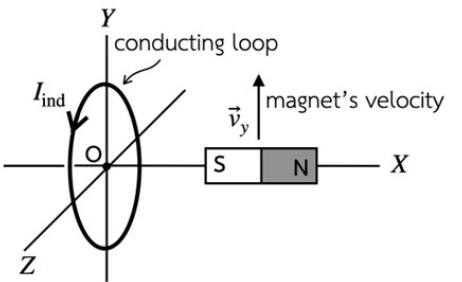
A.	$\rho_C V_A g$
B.	$\frac{1}{2} \rho_A V_A g$
C.	$\frac{1}{2} \rho_B V_A g$
D.	insufficient information

5. Two identical LEDs are connected as shown in the circuit diagram. Each LED needs a current of 10.0 mA and a potential difference of 1.20 V to operate correctly. Calculate the resistance of a resistor R for this circuit to operate under the conditions given above.

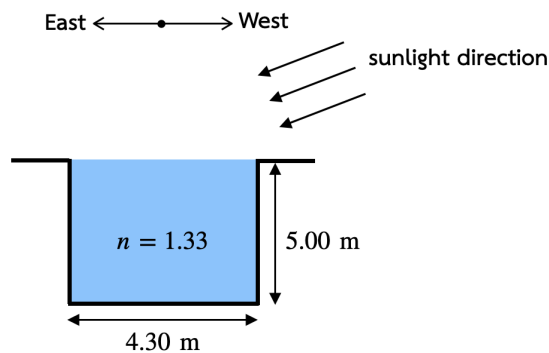


A.	330 Ω
B.	390 Ω
C.	660 Ω
D.	780 Ω

6. Identify the diagram that shows the **incorrect** direction of the induced current I_{ind} in the conducting loop. In all the figures, the conducting loops are in the y-z plane and the currents are in the counter-clockwise direction when viewed from the positive x-axis.

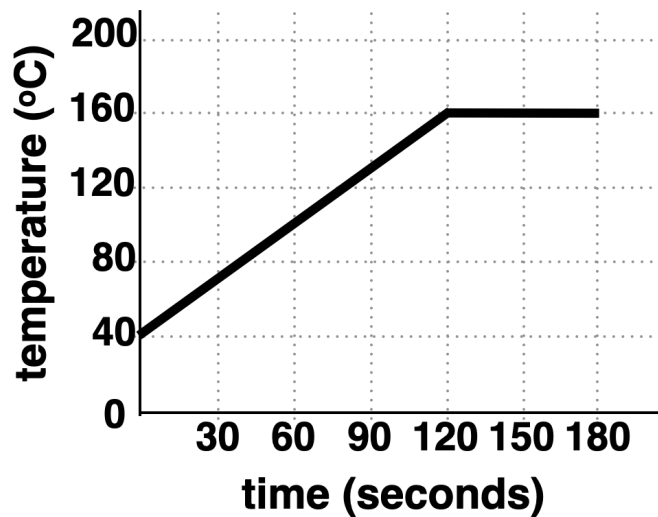
A.			B.	
C.			D.	

7. The rectangular pool measuring 4.30 meters in width and 5.00 meters in depth is filled with water to the top. As shown in the figure, the 4.30-meter side aligns with the East-West direction. The pool is situated near the equator, where the Sun is directly overhead at noon. At approximately what time will the bottom of the pool begin to be entirely shaded? Given that the index of refraction of water is 1.33.



A.	3:00pm
B.	3:30pm
C.	4:00pm
D.	4:30pm

8. An insulated container holds 200 grams of solid thermoplastic. Heat is supplied to the thermoplastic at a constant rate of 400 J/s for 180 s. The temperature of the thermoplastic is measured and recorded, and the results are presented in the graph below.



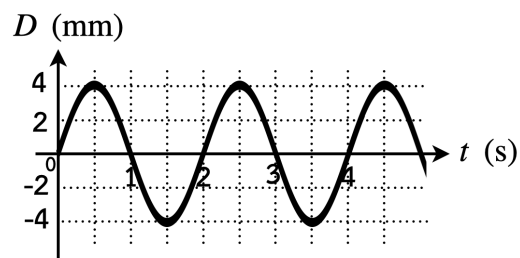
Consider the following statements:

- I. The specific heat capacity of this thermoplastic is 2.00 kJ/(kg K).
- II. The melting point of this thermoplastic is 160 °C.
- III. After 120 seconds, only liquid form of the thermoplastic is in the container.
- IV. The specific latent heat of fusion of this thermoplastic is 12.0 kJ/kg.

Which of these statements is true?

A.	I and II only
B.	II and III only
C.	I, II and IV only
D.	I, II and III only

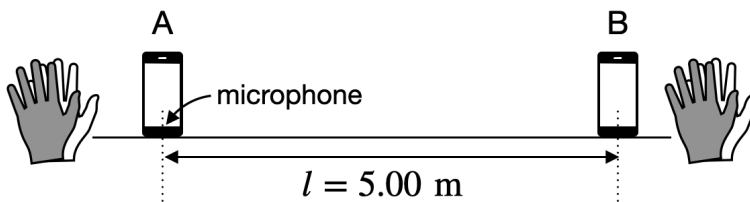
9. The graph below shows the displacement (D) of a medium at $x = 0.0$ cm as a function of time (t) for a wave traveling in the $+x$ direction at a speed of 5.0 cm/s. Determine the wavelength of this wave.



A.	2.0 cm
B.	5.0 cm
C.	8.0 cm
D.	10 cm

10. A smartphone can be used as an acoustic stopwatch. It measures the time interval between two consecutive sound events captured by its microphone. The timing starts when the first sound pulse reaches the microphone and stops when the second sound pulse is detected.

In an experiment aimed at measuring the speed of sound in the air ($v = 340 \text{ m/s}$), two smartphones in acoustic stopwatch mode are placed with their microphones located at a distance $l = 5.00 \text{ m}$ apart, as shown in below figure. During the measurement, one student claps next to the microphone of phone A, and a few seconds later, another student claps next to the microphone of phone B. Each clap triggers both phones but at different moments due to the time it takes for the sound waves to travel. Which of the following are a possible correct pair of readings from phone A and phone B?



A.	Phone A: 0.0147 s, Phone B: 0.0147 s
B.	Phone A: 2.0147 s, Phone B: 2.0000 s
C.	Phone A: 3.1000 s, Phone B: 3.1294 s
D.	Phone A: 2.1294 s, Phone B: 2.1000 s

11. Use data from the table to answer the question.

Indicator	K_A of indicator at 25°C	Color change (acid form to basic form)
Bromophenol blue	1.4×10^{-4}	Yellow → Blue
Bromocresol green	2.1×10^{-5}	Yellow → Blue

Colors of both bromophenol blue and bromocresol green turn yellow when the ratio of acid form: basic form is greater than 25:1, while they turn blue when the ratio of basic form: acid form is greater than 5:1. Both indicators are green in between the pH that corresponds to 25:1 and 5:1 ratios. What color could a solution of bromophenol blue appear if it is at the same pH as a solution of bromocresol green that appears green?

- A. Blue
- B. Green
- C. Yellow or Green
- D. Green or Blue

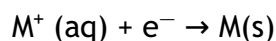
12. From the following observations under standard conditions:

- i. Metal M dissolves in H_2SO_4 (aq), but not in HCl (aq).
- ii. Metal M displaces Ag^+ (aq), but not Sn^{4+} (aq).

When

$2\text{H}^+ + 2\text{e}^-$	$\rightarrow$	H_2	$E^\circ_{\text{red}} = 0.00 \text{ V}$
$\text{Sn}^{4+} + 2\text{e}^-$	$\rightarrow$	Sn^{2+}	$E^\circ_{\text{red}} = 0.13 \text{ V}$
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^-$	$\rightarrow$	$\text{SO}_2 + 2\text{H}_2\text{O}$	$E^\circ_{\text{red}} = 0.20 \text{ V}$
$\text{Ag}^+ + \text{e}^-$	$\rightarrow$	Ag	$E^\circ_{\text{red}} = 0.80 \text{ V}$

Estimate the value of E°_{red} of the half reaction:

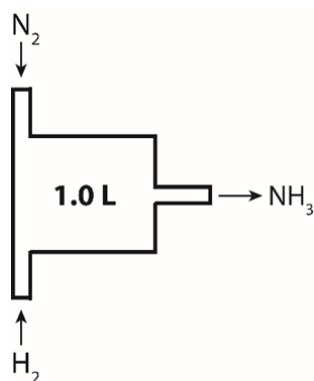


- A. $0.00 \text{ V} < E^\circ$
- B. $0.00 \text{ V} < E^\circ < 0.13 \text{ V}$
- C. $0.13 \text{ V} < E^\circ < 0.20 \text{ V}$
- D. $0.20 \text{ V} < E^\circ < 0.80 \text{ V}$

13. A sample of 0.5 g silver metal is obtained from two different silver sources. Source 1 has two stable isotopes, ^{107}Ag (106.91 g/mol) and ^{109}Ag (108.90 g/mol), with isotope abundance of 51.84% and 48.16%, respectively. Source 2 contains ^{107}Ag (106.91 g/mol) and ^{109}Ag (108.90 g/mol), with isotope abundance of 44.80% and 55.20%, respectively. If the isotope ratio (^{107}Ag : ^{109}Ag) in the the silver sample is 1:1, determine the percentage by mass of silver from source 2 in the sample.

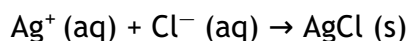
- A. 12%
- B. 26%
- C. 32%
- D. 51%

14. Assume that the reactor under the condition given below starts at vacuum, and then N_2 and H_2 are fed at constant rates of 2.0 g/min and 0.43 g/min for N_2 and H_2 , respectively. Once 8.4 g of N_2 is accumulated in the reactor, ammonia is selectively removed from the reactor at a constant rate to maintain a chemical equilibrium within the reactor. If the equilibrium constant K_c of this reaction is 3.0 at this temperature, how many grams of ammonia are present in the reactor at any given time once equilibrium has been established? (The reaction involved is $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.)



- A. 4.8 g
- B. 8.4 g
- C. 10 g
- D. 14 g

15. A student prepares a 1.0 M solution of $\text{PtCl}_4 \cdot 5\text{NH}_3$. The student first tests the conductivity of the solution and it conducts electricity equivalent to the solution of 4.0 M of ions. The student titrates 10.00 cm^3 of 1.0 M solution of $\text{PtCl}_4 \cdot 5\text{NH}_3$ with a 1.5 M silver solution and 20.00 cm^3 of 1.5 M Ag^+ is required to reach the end point. A titration was performed to determine the amount of Cl^- in the solution according to this reaction.



What are the possible species in the prepared $\text{PtCl}_4 \cdot 5\text{NH}_3$ solution?

- A. $[\text{Pt}(\text{NH}_3)_5\text{Cl}]^{3+} (\text{aq}) + 3\text{Cl}^- (\text{aq})$
- B. $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4] (\text{aq}) + 3\text{NH}_3 (\text{aq})$
- C. $[\text{Pt}(\text{NH}_3)_5]^{4+} (\text{aq}) + 4\text{Cl}^- (\text{aq})$
- D. $[\text{Pt}(\text{NH}_3)_4\text{Cl}_2]^{2+} (\text{aq}) + 2\text{Cl}^- (\text{aq}) + \text{NH}_3 (\text{aq})$

16. An element X is in the third period of the periodic table. The data for successive ionization energy of the element X are $IE_1 = 1012 \text{ kJ/mol}$, $IE_2 = 1907 \text{ kJ/mol}$, $IE_3 = 2914 \text{ kJ/mol}$, $IE_4 = 4964 \text{ kJ/mol}$, $IE_5 = 6274 \text{ kJ/mol}$, $IE_6 = 21268 \text{ kJ/mol}$, and $IE_7 = 25431 \text{ kJ/mol}$. Which of the following statements is correct?

- A. A chloride compound of the element could have molecular formula of XCl_6 .
- B. One chemical formula for the oxide of the element X is X_4O_{10} .
- C. An aqueous solution of any oxide of the element X would turn red litmus paper blue.
- D. Only one unpaired electron can be found in the electron configuration of the ground state atom.

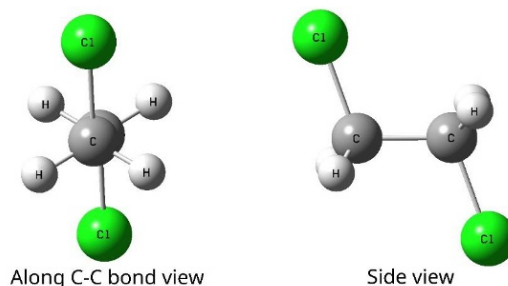
17. If only α (${}^4_2\text{He}$ nucleus) and β^- (e^-) particles (electrons) are emitted during the following chains of natural radioactive decay:

- i. ${}^{232}_{90}\text{Th} \rightarrow {}^{208}_{82}\text{Pb}$
- ii. ${}^{235}_{92}\text{U} \rightarrow {}^{207}_{82}\text{Pb}$
- iii. ${}^{237}_{93}\text{Np} \rightarrow {}^{209}_{83}\text{Bi}$
- iv. ${}^{238}_{92}\text{U} \rightarrow {}^{206}_{82}\text{Pb}$

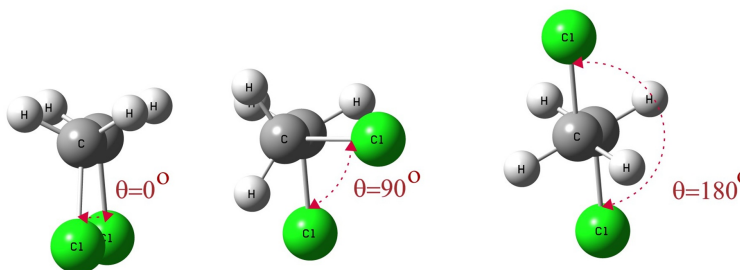
Which decay processes emit the fewest α and the most β^- particles, respectively? (beta decay: $n \rightarrow p^+ + e^-$)

- A. i and ii
- B. iii and iv
- C. i and iv
- D. ii and iii

18. 1,2-dichloroethane or ethylene dichloride (EDC) is a precursor to vinyl chloride which is used to produce polyvinyl chloride (PVC). Its structure is shown below.

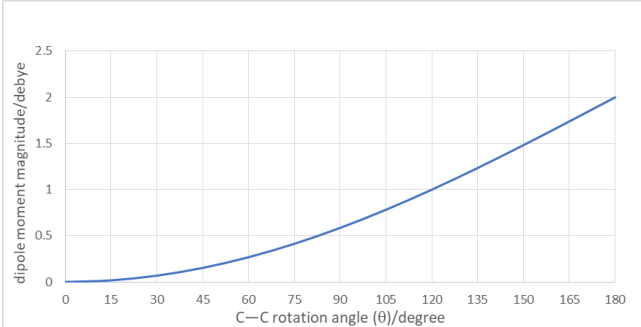
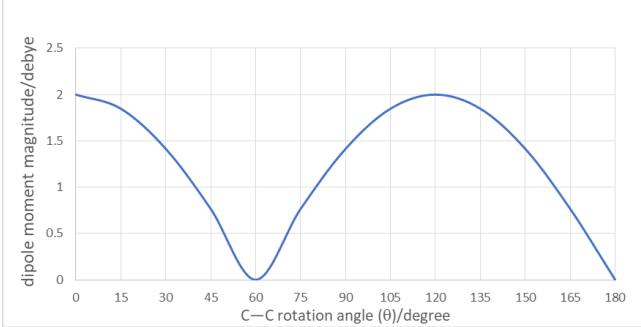
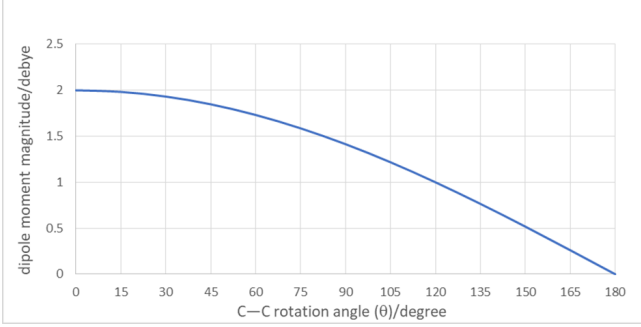
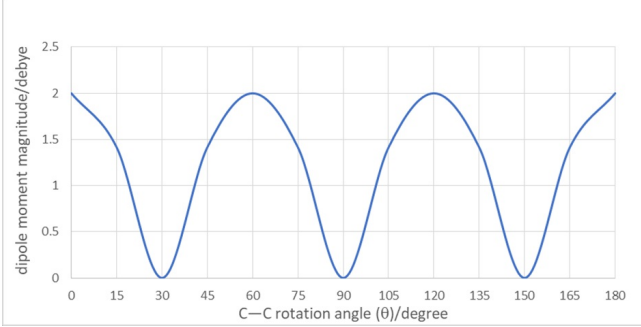


The C—C bond rotation in EDC can occur almost freely. This can be thought of as having one CH_2Cl group stationary and having another CH_2Cl rotating around the C—C axis. Figure below shows the change of molecular structure as the function of C—C rotation angle (θ) viewed along the C—C bond.



The dipole moment is the quantitative measurement of how polar the molecule is. The dipole moment of the molecule can be calculated from the vector addition of bond polarity.

Which is the correct plot of dipole moment magnitude as the function of C—C rotation angle (θ)

A.	
B.	
C.	
D.	

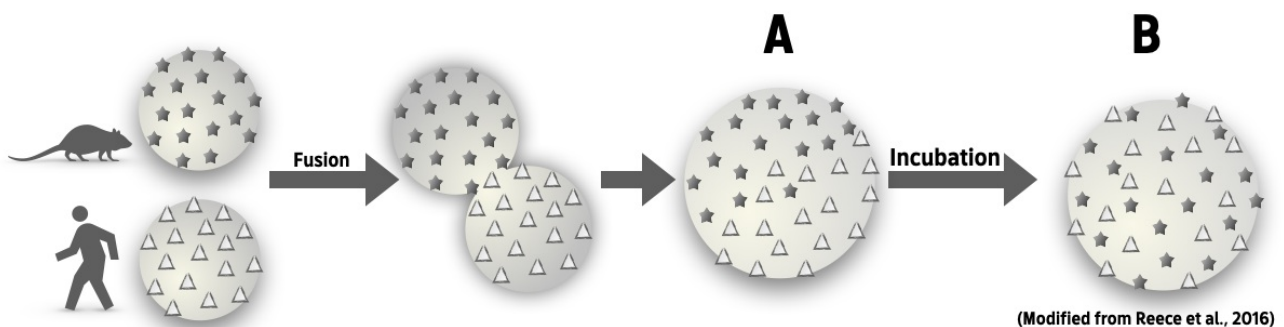
19. A gas mixture with the total mass of 168 g consists of propane (C_3H_8), propene (C_3H_6), and propyne (C_3H_4). It is found that the mass percentage of propene in this gas mixture is 50%. Upon burning this mixed gas in the excess amount of oxygen, the mass of CO_2 produced from the complete combustion of propane is equal to that produced from the complete combustion of propyne. What is the mole fraction of propyne in this gas mixture?

- A. 0.10
- B. 0.25
- C. 0.50
- D. 0.75

20. A series of sulfate samples is to be analyzed by precipitation as BaSO_4 . If it is known that the sulfate content in these samples ranges between 20% and 55% by mass, what minimum sample mass should be taken to ensure that the precipitate mass no smaller than 0.200 g is produced?

- A. 0.150 g
- B. 0.200 g
- C. 0.220 g
- D. 0.412 g

21. Scientists labeled membrane proteins (proteins that exist in the plasma membrane) of a mouse cell and a human cell with two different markers. Two cells were fused forming a hybrid cell. Initially, proteins on the hybrid cell's surface were observed as state A. Normally, after incubating the cell at 37 °C for 1 hour, proteins from different sources would disperse throughout the surface of the cell as in state B.

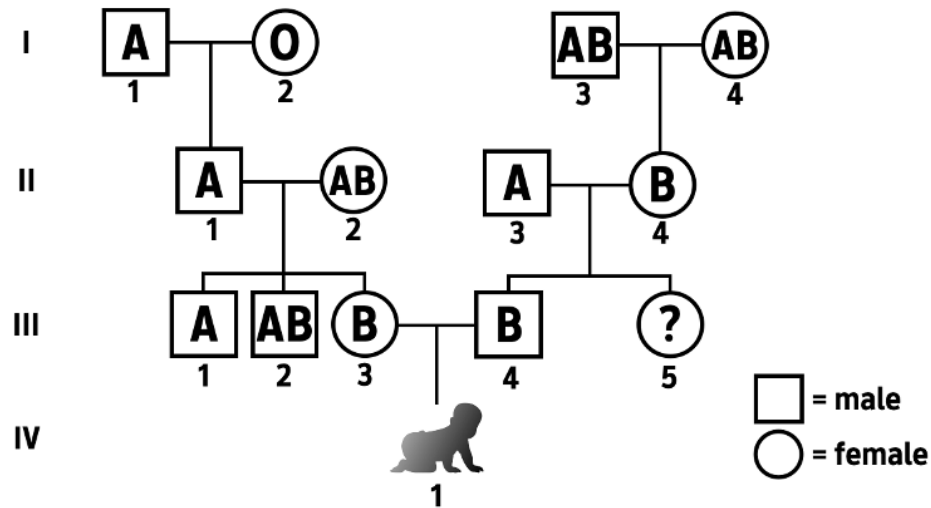


However, if the cell took 2 hours to transform from state A to state B, which of the following could be the reason(s)?

- I. Cell membrane possessed a greater unsaturated-to-saturated phospholipids ratio.
- II. Incubation was carried out at 18 °C.

- A. I only
- B. II only
- C. I and II
- D. neither I nor II

22. The pedigree below illustrates the ABO blood type inheritance of two lineages.

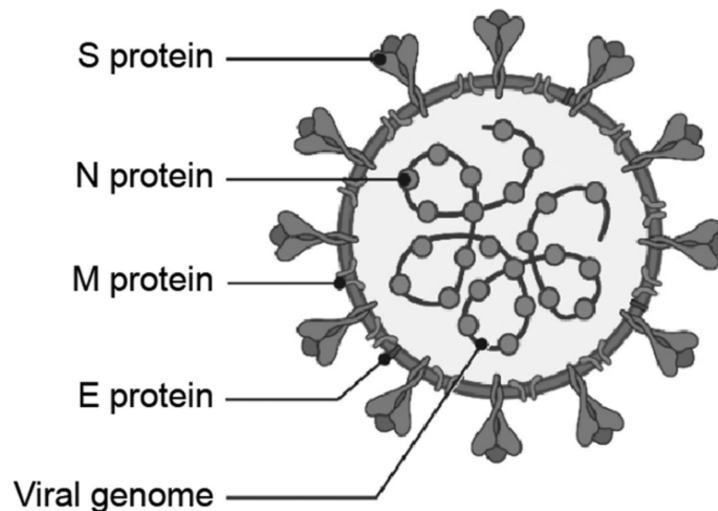


Which statements are true according to the pedigree?

- I. The baby IV-1 cannot be heterozygote.
- II. The probability of III-5 to be a B-type is 0.5.
- III. The genotype of II-1 can either be homozygous or heterozygous.
- IV. If III-1 is married to an AB-type woman, there is a chance for a child to be B-type.

- A. I and II
- B. II and III
- C. III and IV
- D. II and IV

23. The following figure shows the structure of a coronavirus. The virus is an RNA virus that has a lipid-rich envelope derived from the membrane of the host cell.



(Modified from <https://www.biophysics.org/blog/coronavirus-structure-vaccine-and-therapy-development>)

Which of the following statements is **incorrect**?

- A. Chemical analysis should reveal carbohydrate as a component of the coronavirus.
- B. Treatment of the coronavirus with ethanol should denature the viral proteins, rendering the virus non-infectious.
- C. The N protein is expected to have a net negative charge.
- D. The E and M proteins are expected to have hydrophobic amino acids on the surfaces that face the envelope.

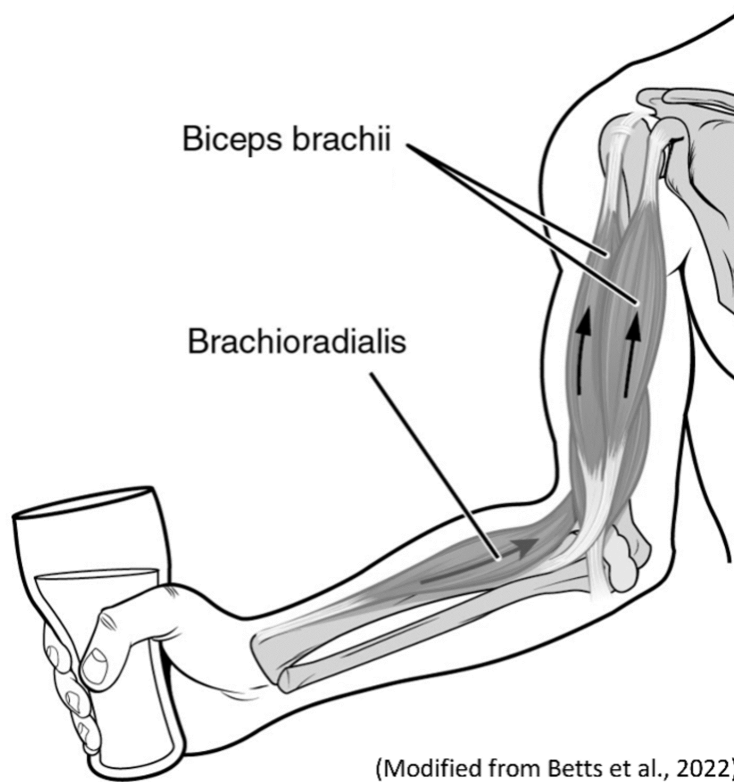


Points: 30

Time: 3 Hours

24. A person is sick from the COVID-19 virus. What kind of immunity does this person gain due to the infection and then retain after recovery?
- A. Active immunity, innate immunity
 - B. Active immunity, acquired immunity
 - C. Passive immunity, innate immunity
 - D. Passive immunity, acquired immunity

25. The figure below shows the biceps brachii, which is a muscle that flexes the lower arm. The arrows indicate the tension force acting on the lower arm bone.



(Modified from Betts et al., 2022)

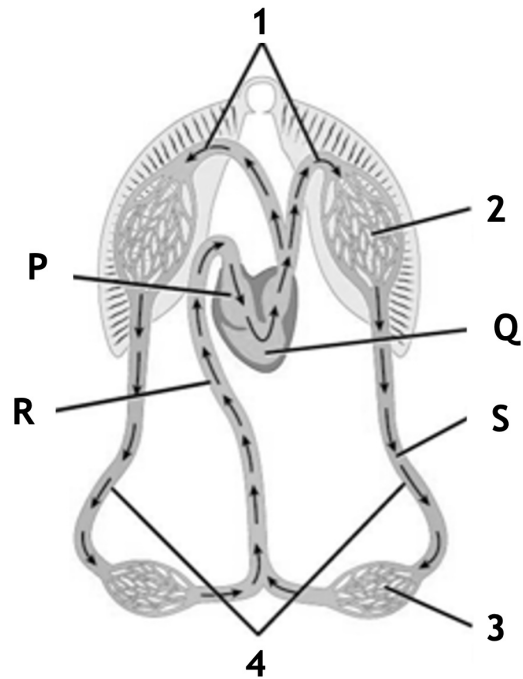
Consider the following statements:

- I. Biceps brachii can be voluntarily controlled.
- II. The muscle cell of the biceps brachii must have a striated appearance with multiple nuclei.
- III. The neurotransmitter released by the motor neurons involved in contraction of biceps brachii is glutamate.

Which statement(s) (I-III) is/are correct?

- A. I only
- B. II only
- C. I and II
- D. I and III

26. The diagram shows blood circulation in a fish. (1: gill circulation, 2: gill capillaries, 3: body capillaries, 4: systemic circulation)



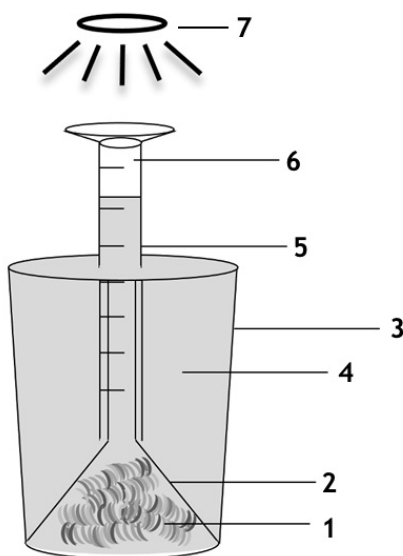
(Modified from Betts et al., 2022)

Which of the following statements are correct?

- I. P is a ventricle of the heart.
- II. Blood in Q is oxygenated.
- III. R is a vein.
- IV. Blood pressure in S is higher than in R.

- A. I and II
- B. I and IV
- C. II and III
- D. III and IV

27. Water thyme (*Hydrilla* sp.) plants (1) are placed inside an upturned funnel (2) in a beaker (3) containing pond water (4) with a small amount of NaHCO_3 added. The end of the funnel is covered with a measuring cylinder (5) in which air (6) was trapped. A light bulb (7) is used as a light source.



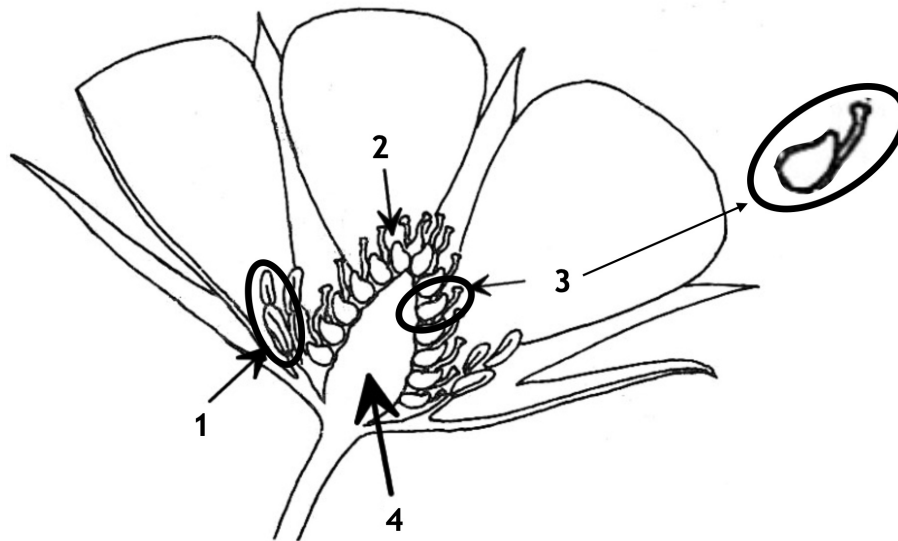
Consider the following statements:

- I. If more NaHCO_3 is added to the water, more bubbles could be observed.
- II. If the light is changed from white to blue light at the same intensity, more bubbles could be observed.
- III. If the light is changed from white to green light at the same intensity, more bubbles could be observed.
- IV. After three hours of the experiment, the air inside the cylinder is mostly carbon dioxide.

Which statements (I-IV) are correct?

- A. I only
- B. I and II
- C. II and III
- D. II and IV

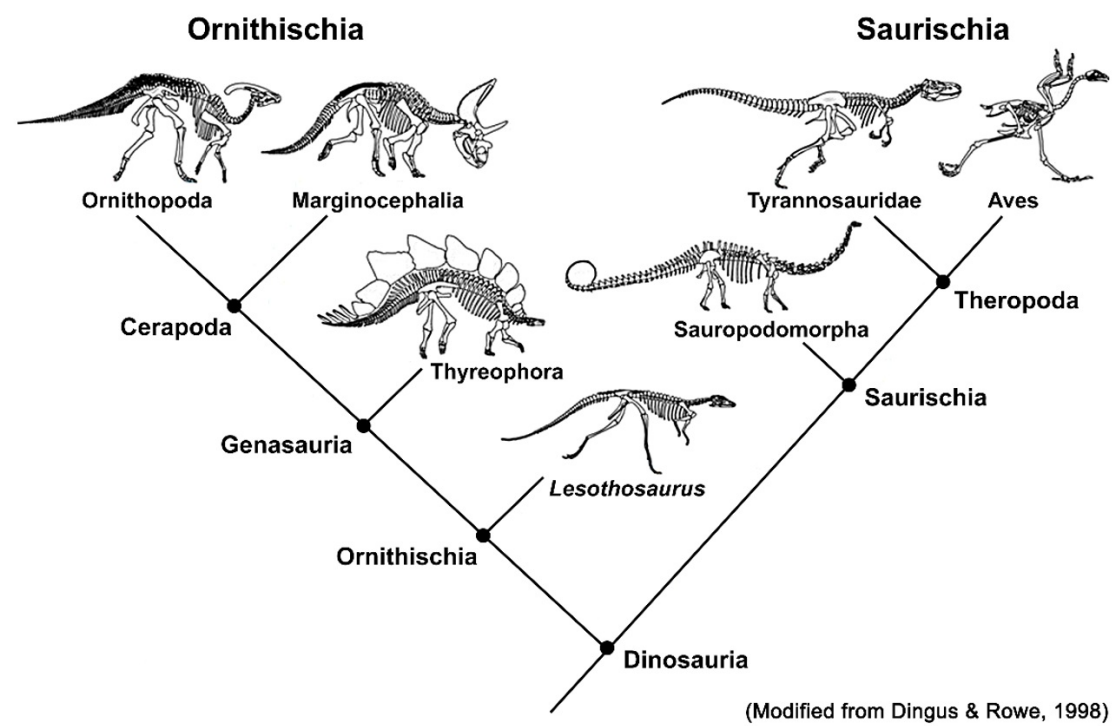
28. According to their development, type of flower, and the number of ovaries, fruits are classified into 3 types: 1. simple fruit, which develops from a solitary flower with a single carpel or several fused carpels; 2. aggregate fruit, which develops from a solitary flower with more than one separate carpel, each forming a fruit; and 3. multiple fruit, which develops from an inflorescence with many dense florets, and the ovary walls are fused together into one fruit. If the flower shown in the diagram is fertilized, which type of fruit will be developed? (1: stamen, 2: carpel, 3: pistil, 4: receptacle)



(Modified from <https://fruit.umn.edu/content/flowers-to-fruit>)

- A. A simple fruit
- B. An aggregate fruit
- C. A multiple fruit
- D. A fruit with many seeds

29. Most of the dinosaurs are members of two lineages, namely Ornithischia and Saurischia. Ornithischia includes the bird-hipped dinosaurs, while Saurischia includes the lizard-hipped dinosaurs. The cladogram illustrates the relationships of these lineages. Modern birds were apparently descended from the saurischians; however, they possess hips similar to those of the relatively unrelated ornithischians.

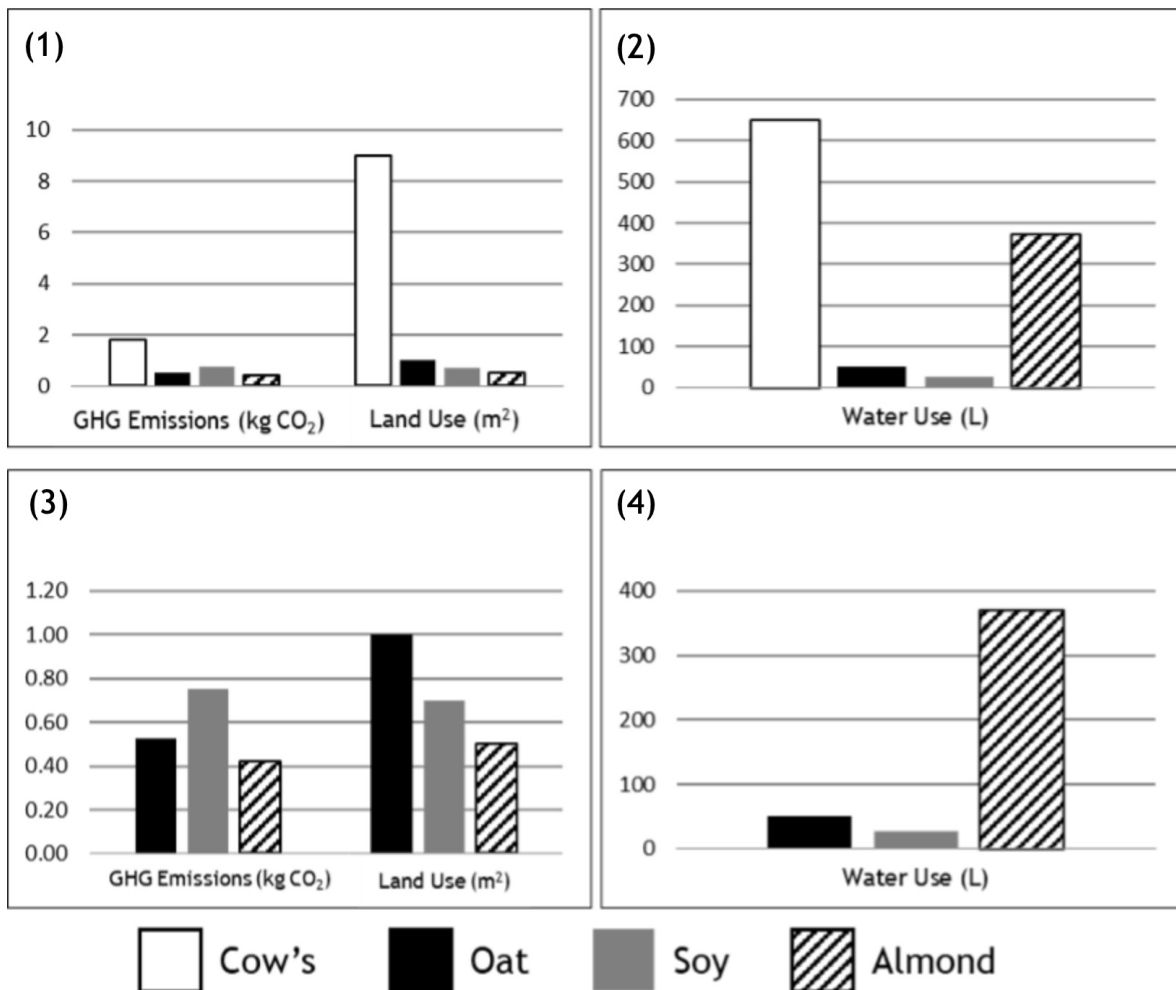


Which of the following correctly explains the hip similarity in birds and ornithischians?

- A. Adaptive radiation of the modern birds
- B. Convergent evolution with the ornithischians
- C. Divergent evolution with the ornithischians
- D. Descent with modification from a common ancestor of the saurischians

30. One of the suggested solutions to reduce greenhouse gas (GHG) emissions and climate change for a more sustainable future is to find alternatives in our diets, such as switching to plant-based milk instead of cow's milk. But are they really more environmentally friendly? Growing the crops and the production processes of these goods are not without their impacts. The environmental resources that are required for, and the GHG emissions that result from, production are important considerations. The following graphs show the global average of GHG emissions (kg CO₂), land use (m²) and water use (L) in the production of one liter of milk product.

- Graphs: (1) GHG emissions and land use of all milk products
 (2) Water use of all milk products
 (3) GHG emissions and land use of plant-based milk products
 (4) Water use of plant-based milk products



The width of the bars is not relevant in the analysis of the question.

Consider the proposed plant-based milk products' suitability as alternatives to cow's milk. Which of the following statements are supported by the data?

- I. All of the proposed plant-based milk products are reasonable alternatives to cow's milk.
- II. Considering all factors, soy milk is the best alternative to cow's milk.
- III. Based on the percentage difference, almond milk is the worst alternative to cow's milk overall.
- IV. Compared to oat milk, cow's milk is worse for the environment in terms of land use than it is in terms of water use.
- V. Almond milk's water requirements make it unviable as an alternative to cow's milk.
- VI. Oat milk is not the best alternative to cow's milk for any given factor.

- A. I, II, and IV
- B. I, III, and VI
- C. II, III, and IV
- D. II, V, and VI